DESIGNING A BLOW MOULDABLE BOTTOM FOR AN INSPECTION CHAMBER

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ABSTRACT

This bachelor´s thesis was made for Uponor Group. The goal of the thesis was to design a producible 560 mm inspection chamber bottom. The work included designing the shape and stress simulations for the product. The shape was drawn with the SolidWorks 3D CAD design software and the stress simulations were done with COSMOSXpress stress simulation software.

The development process proceeded according to the Uponor Stage-Gate© process. Extrusion blow moulding was chosen to be the production method for this product mainly because a 400 mm chamber bottom had already been designed for extrusion blow moulding. The chamber bottom was previously done by machining it from a solid plastic lump. The new bottom would cut costs and material loss. The biggest changes between the 400 mm and 560 mm bottoms were in the size, in the water directing shape and in the reinforcement structure. Also the 560 mm bottom's inlet connections sector was reduced to 120 degrees because the new water directing shape works better then.

In the end eight different bottoms were created. Four different outlet connection diameters and two different diameters for riser-pipe were integrated in these models. From these eight different models four drawings with the strategic measurements of the product were created.

Key words: inspection chamber bottom, blow moulding, drain water piping

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TIIVISTELMÄ

Tämä opinnätetyö tehtiin Uponor Groupille. Tämän työn tavoitteena oli luoda tuotantoon 560 mm tarkastuskaivon pohja. Tähän työhön kuuluu muodon luominen ja lujuusanalyysit tuotteelle. Tuote piirrettiin käyttämällä SolidWorks 3D CAD- piirustusohjelmaa ja lujuusanalyysit tehtiin COSMOSXpress- rasitussimulaatio ohjelmalla.

Suunnitteluprosessi eteni Uponor Stage-Gate © -prosessin mukaan. Ekstruusiopuhallusmuovaus valittiin tuotteelle valmistusmenetelmäksi, pääasiassa siksi, että 400 mm:n kaivonpohja oli suunniteltu aikaisemmin ekstuusiopuhallusmuovattavaksi. Kaivonpohja oli aikaisemmin tehty umpimuovisesta kiekosta työstämällä se halutun muotoiseksi. Uusi pohja pienentää kuluja ja vähentää materiaalin hävikkiä. Isoimmat erot 400 mm ja 560 mm pohjan välillä ovat koossa, vettä ohjaavassa muotoilussa ja tukirakenteissa. Lisäski 560 mm pohjan tuloaukkojen sektori pienennettiin 120 asteeseen, koska silloin vettä ohjaava muotoilu toimii paremmin.

Lopulta luotiin kahdeksan erilaista pohjan mallia. Neljä eri poistoputken halkaisijaa ja kaksi eri nousuputken halkaisijaa sisällytettiin näihin malleihin. Näistä kahdeksasta mallista luotiin neljä piirustusta, joista ilmeni tuotteen strategiset mitat.

Avainsanat: tarkastuskaivon pohja, puhallusmuovaus, sadevesijärjestelmä

CONTENTS

1 INTRODUCTION

This Bachelors's thesis was made for Uponor Oy. The work is a part of a project to automize the production of the 560 mm inspection chamber. The objective was to design a new chamber bottom that can be handled by a robot. The old bottom was made by machining it from a piece of solid plastic and thus it was too heavy and too uniform for a robot to grab. It was decided that the production method of the bottom would be extrusion blowmoulding. A 400 mm bottom had already been designed for a smaller inspection chamber and this bottom was used as a starting point for the design of the 560 mm bottom. A picture of the inspection chamber is in Appendix 2. Appendix 1 has the original picture but in Finnish.

The 560 mm bottom design would also need some strength calculations to make sure that it endures the test that is required of the inspection chamber. These calculations were made by using COSMOSXpess.

2 UPONOR

2.1 The company

Uponor is the leading provider of plumbing and indoor climate systems in Europe and North America. Uponor is also the market leader in infrastructure pipe systems in the Nordic countries. Uponor operates in 30 countries and has 11 factories in 6 countries. The company employs ca. 3 800 persons. Net sales in the year 2008 were EUR 950 million. Uponor's businesses can be divided into three groups: plumbing solutions, indoor climate solutions and infrastructure solutions.

The history of Uponor began on 13 August 1918, when Aukusti Asko-Avonius established a carpentry workshop in Lahti. The workshop soon developed into the largest furniture supplier in the Nordic countries and the largest furniture retailer chain in Finland. The company's name Asko was Finland's best known trademark in the 1930s. Asko founded a sister company called Upo Oy, which became a diversified metal industry supplier. Upo opened a plastics plant in Nastola in 1965 and started to manufacture plastic pipes. In 1982 Asko established a subsidiary named Oy Uponor Ab, which was to focus on plastic pipe production. Asko merged with Uponor in 1999, and the organisation assumed the name Uponor Corporation. (Uponor Group 2009a, b.)

2.2 Product and systems development

Uponor's Product and Systems Development Department is engaged in several ongoing development projects. The projects follow the Stage-Gate® process. The goal of the department is to keep Uponor the leading company in its field and to improve the company's turnover.

2.3 Stage-Gate Portal

Uponor's Stage-Gate® process covers the entire life cycle of a product from the idea to the end of the product's life. It is an efficient tool for the development, introduction and phase out of offerings within Uponor. The Stage-Gate® process uses stages and gates. The operation is divided into stages. During a stage the project team gathers information needed to advance to the next stage. However, before the product can reach the next stage it must go through a management decision gate were the project is evaluated. At a gate mediocre projects are eliminated and resources are directed to the best projects. There are nine stages and gates starting from idea and ending at termination approval. Before the final gate it may be decided that the product needs improving, and then the process starts from the beginning. The whole Stage-Gate® process can be seen in Figure1. (Uponor Group 2009c.)

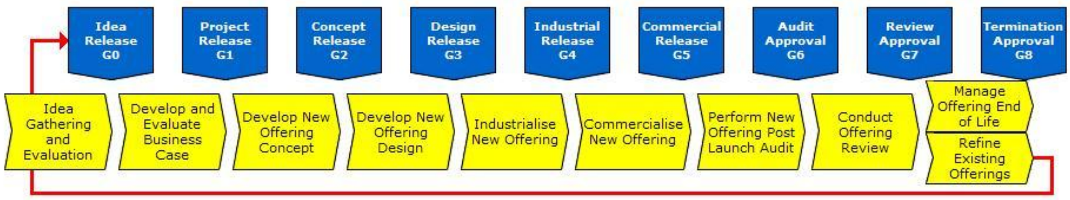

Figure 1. Uponor Stage-Gate® process (Uponor Group 2009c.)

2.4 Develop new offering design

The develop new offering design stage takes place after concept release and the goal is to have new offering design. In this stage the draft technical specifications are made for the product itself, tooling and material. A prototype is made and tested. Requirements for the production method are specified. Suppliers of the production method are examined and price levels are analyzed. Internal and external plans are further developed and detailed. The stage ends with a finalized offering design. It is checked with all the other deliverables in the gate-decision meeting for completeness according to the exit criteria for the gate. If the stage does not meet the exit criteria, the project will be filed for possible use in future. (Uponor Group 2009d.)

3 INSPECTION CHAMBER

The inspection chamber is intended for directing wastewater and inspecting the sewer system. It can also be used as a rainwater inspection chamber and a well. The chamber gathers the water from inlet pipes and directs it into the outlet pipe. The 560 mm diameter chamber is used mainly in municipal piping but the 400 mm chamber is also used in the private sector.

3.1 The chambers

There are two kinds of chambers used for this purpose: the Uponor Pro inspection chamber for wastewater and rainwater management, which has a SFS approval, and a handmade inspection chamber for wastewater and rainwater management. The system image of handmade inspection chamber is seen in Finnish in Appendex 1 and in English in Appendix 2. In the Uponor Pro inspection chamber the inlet pipes come directly into the chamber in a predefined angle and diameter. In the handmade inspection chamber the inlet pipe connections are made according to the customers needs. The customer chooses the number, the angle, the height and the diameter of the inlet pipes, and the diameter of the outlet pipe. (Uponor kaivot 2006)

The handmade inspection chamber can have two kinds of riser pipes. One is triple layered and made from PE-HD and the other is solid walled and made from PP. The triple layered PE-HD riser has a smaller inner diameter and larger wall thick-ness than the solid PP riser.

The old handmade inspection chamber version is accordant with the SFS 3468 standard. The SFS 3468 standard tells the quality requirements of plastic inspection chambers and wells for underground applications. (SFS 3468; Uponor kaivot 2006)

3.2 Standardised test for inspection chamber buckling resistance

The inspection chambers have a standardized testing method. They are tested according to the EN 14830 and SFS 3468. This test method should simulate the condition of 50 years of underground usage. This test is done by applying low pressure inside the chamber in a heated environment. (Uponor kaivot 2006)

4 DESIGN GUIDELINES FOR PLASTIC PRODUCTS

4.1 Surface quality

Surface quality can be divided into three different groups: surfaces that are clearly visible and need good surface quality, those that are visible but not so clearly and need adequate surface quality, and those that are not visible and do not need to have any quality. Surface quality also has an influence on ejecting of the product from the mould. Smooth surface comes out from the mould more easily and does not need so much annealing than a rough surface with the exception of polypropylene. (Järvelä, Syrjälä, Vastela 2000, 285)

4.2 Strength

The product must be strong enough to endure its normal use for the desired time. To increase the strength of a plastic product, its wall thickness can be increased but this usually causes more negative effects like distortions and sinkmarks rather than increasing the strength. Better ways of increasing the strength are using single or double curved surfaces and reinforcement ribs. In hollow objects kiss-off and tackoff surfaces increase the strength by making the object more uniform. (Päivinen, 26; Järvelä, ym. 2000, 300)

4.3 Filleting

Round corners are common in plastic products because they divide the stress more evenly than sharp corners. A common rule for the minimum radius of the curvature is 1.5 times the wall thickness (Järvelä, ym. 2000, 302). In blow moulding, if the radius is too small, the material may not fill the mould completely, thus leaving an uneven edge, ruptures and possibly even burn marks. (Järvelä, ym. 2000, 302)

5 EXTRUSION BLOW MOULDING

5.1 Process description

Blow moulding processes are used to create hollow plastic containers, bottles and parts. In the extrusion blow mouldig process the thermoplastic is first molten by an extruder. Then the melted plastic goes through a die which forms it into a tubular shape. This tube is formed into a preform leaving a hole in the end in which compressed air can pass through. This preform is then captured by closing it into a mould cavity where it is inflated using compressed air. The compressed air presses the plastic against the walls of the mould cavity. When the plastic is cooled sufficiently the mould opens and the part is ejected and the flash is cut. (Wikipedia 2009)

5.2 Wall thickness

The extrusion blow moulding process creates different wall thicknesses in different parts of the product. This happens because the plastic has to stretch different lengths in different parts of the mould. The wall is thinnest where the wall of the mould cavity is furthest from the preform and thickest where the wall is near the preform. If the plastic stretches too much or there are sharp edges in the mould, the plastic can rupture. (Wikipedia 2009)

The wall thickness distribution is best when it is taken into account in the design stage. Using a large radius in corners and curved faces create a more uniform wall thickness. If the desired wall thickness cannot be achieved by shape it may be achieved with two other methods. One method is shaping the die to the right shape. The other method is programming. Programming controls the wall thickness of tubes from top to bottom. (Wikipedia 2009)

6 EXTRUSION WELDING

6.1 Extusion welding method

Extrusion welding is used for attaching thermoplastic parts together. The principle of extrusion welding resembles plastic extrusion. Plastic is fed to a screw where the plastic is melted. At the same time hot gas is used to melt the weld joint. The screw pushes the molten plastic through an end piece. The end piece is used to press the molten plastic against a weld joint and give it the proper shape. To ensure a good weld the plastic that is fed by extrusion is usually the same as the plastics that are joined.

6.2 Extrusion welding in inspection chamber

In the tailor made inspection chamber the bottom is attached to the riser pipe using extrusion welding. Also the muffles are attached to the riser pipe by extrusion welding. The old bottom was inserted in the riser pipe and welded together. This method was too inaccurate for a robot. A flange was designed for the 400 mm bottom to ensure that the bottom is always installed to the same depth. The shape of the flange was designed so that a good weld joint is always achieved.

7 DESIGNING THE BLOW MOULDABLE SHAPE

7.1 Designing the kiss-off structures

From the new specifications new blow mouldable models could be made. The blow mouldable shape meant that the bottom, the alignment crevice, the extended flow shape, the reinforcement structure and the center of the part had to be drawn. The center of the part had to be made hollow, leaving approximately 7 mm wall thickness. The reinforcement was done by kiss-off surfaces shaped as circular frustums. The kiss-off structure connects the upper and lower surfaces of the bottom, thus giving it stiffer structure.

Three kiss-off structures in the middle of the bottom were done exactly the same as in the smaller 400 mm bottom. These were left unchanged because the assembly robot grabs the bottom from these three holes. The other holes could not be copied from the 400 mm bottom because the bottom would not be strong enough to withhold the standardized test. Five models with different shape, size and number of frustums were designed and tested with the COSMOSXpress structural analysis program.

7.2 Aligment crevice

An aligment crevice was designed to the the side of the outlet groove. This was done to the same shape as the crevice in the 400 mm bottom. Only the distance from the center of the part is different. With the help of the crevice the robot always takes the bottom in the right way.

7.3 COSMOSXpress

COSMOSXpress is a structural analysis program used for objects designed with SolidWorks. The program simulates what will happen to designed objects under stress. Before simulation certain parameters must be enteredt in to the program. These parameters are material, restraint and load. After the parameters are put in, the program creates a mesh and runs the analysis. The program shows the sress distribution, displacement distribution or deformed shape of the model.

7.4 The structural analysis

For this analysis PE-HD was chosen from the programs list, the restrain was the flange which is held against the end of the pipe and the flow surface was chosen to the load surface. The amount of the load was 0.6 bar vacuum or 60000 Pa. This was to simulate the conditions of the standardized test.

7.5 The results of the structural analysis

From the tests can be noticed that the least deformation occurs in parts that have long shapes going away from the center to the edge. The maximum amount that can be allowed in these tests is 5.6 mm, a tenth of the diameter of the inspection chamber.

The model with eight elliptical frustums and two small circular frustums, has the smallest deformation, approximately 3.2 mm, but the number of the frustums makes this model hard to produce. The model with six elliptical frustums, has a larger deformation, approximately 4.1 mm, but because of the simpler shape this model is feasible for production. In model with four large and two small frustums, the deformation is 3.4 mm and, the model with six smaller frustums the deformation is 3.8 mm, but in both of these the shapes are too hard to manufacture. The model with six circular frustums was made like the 400 mm bottom, only the diameter and the number of the frustums was changed. This was believed to be the easiest to manufacture. The deformation of this model was the largest, approximately 4.7 mm, but this was within the limits. So the model similar to the 400 mm bottom was chosen.

Later it was noticed that the frustum under the outlet groove came too close to the outlet-hole in models with 250 mm and 315 mm outlet holes and this could cause a problem in production. The models were tested with COSMOSXpress without the frustum and with a smaller frustum that is similar to the three small frustums, which could probably be manufactured. In both cases the deformation was whitin the limits, so it was decided to change to the small frustum.

7.6 The behaviour of the bottom in the standardized test

Although most of the deformation occurs in the middle of the product, the largest increase of deformation occurs at the edge of the product. The product used in the test was modified so that it could be manufactured, so it was not the same as the one used in the COSMOSXpress simulation. The largest differences between the CADmodel and the real product are the wall thickness, the shape of the flange and that some of the kiss-off surfaces designed were left out. This can also partly explain the difference between the simulation tests and the standardized test.

7.7 The flange

A flange was designed to the 400 mm bottom and the 560 mm bottom. The flange is put against the end of the riser-pipe, thus making sure it always goes to the same depth. The flange also helps to seal the inspection chamber. This is why the flange also needs to be flat. The diameter of the flange is 559 mm. Depending on the type of the riser-pipe, the width of the flange is either 14 mm or 21 mm. The flange is tapered to 15 degrees so that it would be easy to get out from the mould. The height was set to 20 mm.

8 THE ASSEMBLY OF THE INSPECTION CHAMBER

The inspection chambers are assembled in a factory according to the customer’s needs. The customer has to choose the following features for their inspection chamber: the diameter and the height of the chamber, the type of the riser-pipe, the diameter of the outlet-pipe and the diameters, angles, heights and the number of the inlet pipes.

After an order comes to the factory, the riser pipe is cut to the desired length and inlet- and outlet-holes are cut to the pipe. After that the bottom is attached to the riser pipe by welding it with the extrusion welding method along the edge of the flange. The fange also makes sure that the bottom always goes to the same depth and a step in the outlet-side ensures that the outlet-muffle goes to the correct position. The extrusion welding also seals the chamber.

9 FINISHING THE DESIGN

9.1 Last steps before design release

The basic features of the bottom are now complete but there are things that need to be done before the bottom is complete. These things include the stamp, blueprints and checking all of the dimensions.

The 560 mm bottom had four different dimensions for outlet grooves and two different diameters for the riser-pipe. This means that there are eight different models. The dimensons were checked by two persons so that nothing was missed.

9.2 The stamp

The stamp was mandatory in this part so that it could be traced. The stamp had to have the manufacturer’s logo, the subcontractor’s name, the recycling symbol, the year clock and the maximum depth of installation. The stamp needs to be in a place that is visible. In these chamber bottoms the stamp is placed to the backside. The staps background is 0.6 mm submerged and the features are at the same level as the rest of the backside. The background of the stamp is polished.

9.3 Visit to the subcontractor

In this case the subcontractor makes the mould and the mass production of the bottom. The subcontractor was visited because their opinion about certain features was needed. They suggested that frustums should have larger filleting in the corners and more height to the flange. They also stated that the diameter of a frustum should be greater than the depth of the frustum. The fillets were made a few millimeters larger, but the flange and the frustums were left as they were.

9.4 Drawings

Four different drawings were made. Each of them showed two models. Strategic measurements were shown for both of the models, the stamp as a detail and the bottom from top, bottom and back and isometric views for both of them. The drawings also had the drawing number, the company's logo, the designer's name, the weight and the material of the product and the drawing's title.

10 SUMMARY

The design project of blow mouldable 560 mm chamber bottom was completed successfully. The product passed G3 Design Release Gate and advanced to the next stage.

The biggest problems in the design phase were with the SolidWorks program. The shape that was designed to direct the water was multicurved and this led to a number of problems that prolonged the design phase. With more insight to the program these problems might have been avoided. After the design phase, the bottom designs were sent to the subcontractor and with minor changes they were able to start the production of the bottom.

The strength calculations were put to a test when the manufactured bottom was applied to the standardized test. The bottom endured the test as the COSMOSXpress simulations suggested and mass production was started. Blow moulding might not be the easiest method for this type of product but it achieved the goals that were set for it.

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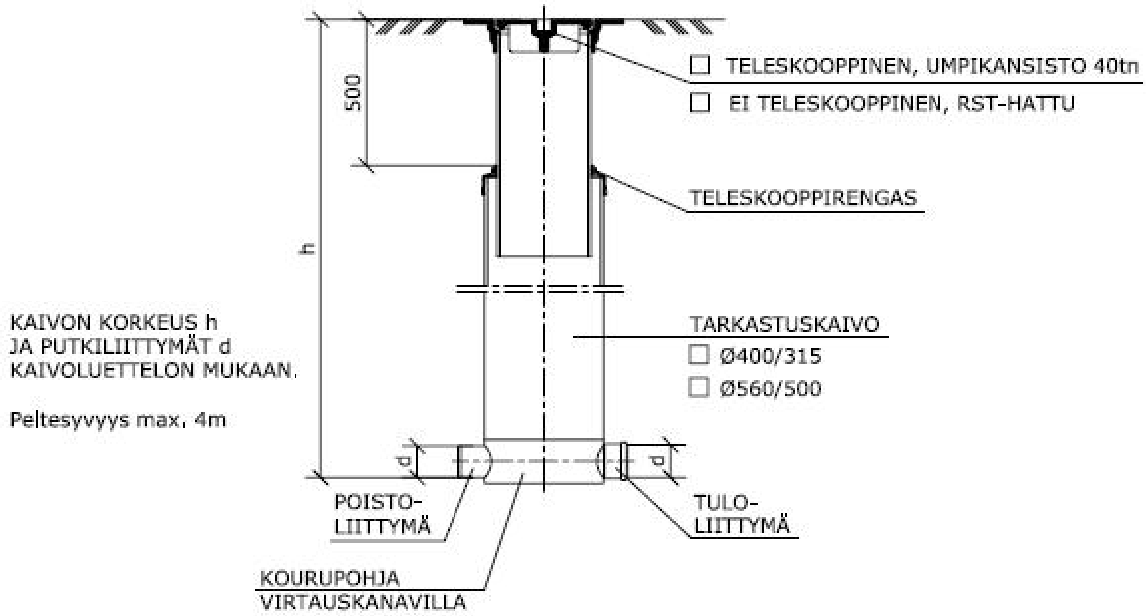
UPONOR KOURUPOHJALLINEN JÄTEVEDEN TARKASTUSKAIVO



Valmistaja: UPONOR SUOMI OY

Pidätämme oikeuden muutoksiin

K.osa/Kylä Kortteli/Tila Tontti/Rn:o	Viranomaisten arkistointimerkintöjä varten
Rakennustoimenpide	Piirustuslaji Juoks.n:o
Rakennuskohteen nimi ja osoite	Piirustuksen sisältö Mittakaavat
Suunnittelijan nimi, päiväys ja allekirjoitus	Suunnitteluala, työn n:o ja piir. n:o Muutos

UPONOR INSPECTION CHAMBER
BOTTOM WITH GROOVE BOTTOM